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(54) **Antenna element**

(57) A radiating antenna element (100), comprising a metallic patch (1), the patch (1) having a cup-shaped form and comprising a substantially rectangular substantially planar member (102) and a sidewall (5a, 5b, 5c, 5d) extending transverse to the plane of the planar member (102) from each edge (106a, 106,b, 106c, 106d) of the planar member (102). A cut-out (6a, 6b, 6c, 6d) is defined at each corner of the patch (1), whereby at each corner edges of respective pairs of sidewalls (5a, 5b, 5c, 5d) are spaced apart by a distance such that the radiating antenna element is capable of ultra-wideband operation (e.g. signal bandwidth greater than or equal to (i) 25%, (ii) 30%, (iii) 35% or (iv) 39% of the centre frequency). The antenna element (100) further includes at least a metallic first feed probe (4a), the first feed probe (4a) being coupled to the patch (1) at a position at or adjacent a first corner thereof, providing for operation with a first slant linear polarisation. A second feed probe (4b) may be coupled to the patch (1) at a position at or adjacent a second corner of the patch (1), the second corner being at an opposite end of one of the sidewalls (5a, 5b, 5c, 5d) extending to the first corner of the patch (1). The second feed probe (4b) provides for operation with a second slant linear polarisation, whereby the direction of that second polarisation is oriented at substantially 90° to the direction of the first slant linear polarisation. The feed probe(s) (4a, 4b) may be mounted within the cut-outs (6a, 6b, 6c, 6d).The antenna element (100) may further include a metallic pedestal (3), the patch (1) being mounted so as to define a spacing (7a) between the patch (1) and the pedestal (3), wherein (i) the spacing (7a) comprises an air gap, (ii) a dielectric spacer is disposed in said spacing (7a), or (iii) the spacing (7a) is provided by a combination of an air gap and a dielectric spacer. Further feed probes, or support elements (8c, 8d) may be provided at the corners opposite the at least first (4a) and second (4b) feed probes. A cup-shaped patch for use in the antenna element (100) is also disclosed.

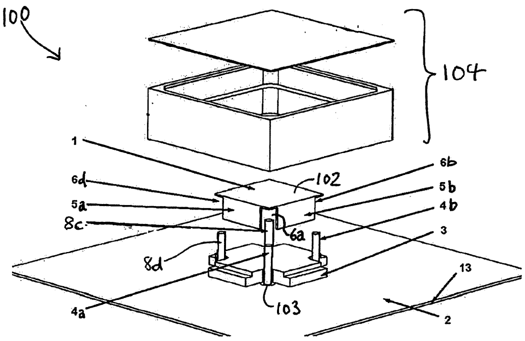

FIGURE 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to antenna elements for mobile telecommunications and more particularly although not exclusively to an ultra-wideband radiating antenna element.

BACKGROUND OF THE INVENTION

[0002] Mobile telecommunications systems based on networks of nodes are well established, with user equipment (UE) such as a handheld device connected to a base-station (defining a corresponding macrocell, small cell, etc.).

[0003] The trend in the design of antenna arrays for mobile base-station applications is toward radiating antenna elements with ever-increasing operating bandwidths. Modern base-station antennas typically utilize one or another form of the log-periodic dipole antenna - known for its wide intrinsic bandwidth and excellent polarization purity - as the radiating element, wherein the radiating element is either a single log-periodic dipole antenna, for single-polarization operation, or the radiating element consists of a pair of crossed log-periodic dipole antennas, for dual-polarization operation.

[0004] In operational installations, each such an antenna element is cantilevered by its base from a substantially vertical, flat elongated panel, which serves as an electrical ground plane for the radiating elements and a mechanical support of the overall antenna. Due to the inherent size, mass and cantilevered configuration of the antenna elements, log-periodic dipole antenna elements rely on fasteners, such as screws or rivets, to attach the antenna elements to the ground plane. Consequently base-station antennas employing log-periodic dipole radiating elements have several drawbacks and limitations. Firstly, the inherent size of the radiating elements does not make the antenna elements amenable to low-profile solutions; this, in turn, means the elements are not well suited for installations where factors such as wind load (e.g., in highly-exposed macrocell base stations) or aesthetic considerations (such as common for microcell and femtocell base stations) are of importance. Secondly, the log-periodic antennas have low gain per unit of weight, as only a small subset of the dipole elements are active on a given frequency, the remaining dipole elements being inactive; typical peak gain of log-periodic dipole antennas used as radiating elements in base-station antenna arrays does not exceed 4.5 dBi. Thirdly, the metal-to-metal connections in the attachments of the cantilevered radiating elements to their ground plane increase the risk of passive-intermodulation interference, which can have crippling effects on the radio-frequency performance of the entire base station. Furthermore, the antennas are typically so wide-banded that they have only very little natural out-of-band frequency discrimination, thereby necessitating (more-expensive) receive filters with steeper rejection slopes.

[0005] An inverted patch of U-shaped cross-section can be used as radiating element, and was conceived to reduce the antenna footprint and produce a more-compact design. However, this design does not provide dual-slant linear polarization or ultra-wideband operation.

SUMMARY OF THE INVENTION

[0006] According to a first aspect of the invention, there is provided a radiating antenna element, comprising: a metallic patch, the patch having a cup-shaped form and comprising a substantially rectangular substantially planar member and a sidewall extending transverse to the plane of the planar member from each edge of the planar member; a cut-out defined at each corner of the patch, whereby at each corner edges of respective pairs of sidewalls are spaced apart by a distance such that the radiating antenna element is capable of ultra-wideband operation; and at least a metallic first feed probe, the first feed probe being coupled to the patch at a position at or adjacent a first corner thereof.

[0007] An advantage is that embodiments of the invention substantially exceed the requirement for ultra-wideband operation: embodiments presented herein achieve an absolute bandwidth of 750 MHz and a relative bandwidth of 39%.

[0008] The distance between respective pairs of sidewalls may be such that (a) the antenna element is capable of emitting a signal bandwidth greater than or equal to (i) 25%, (ii) 30%, (iii) 35% or (iv) 39% of the centre frequency of the antenna element, and/or (b) the first feed probe may be mounted within the cut-out.

[0009] The antenna element may further comprise a second feed probe. The second feed probe may be coupled to the patch at a position at or adjacent a second corner of the patch, the second corner being at an opposite end of one of the sidewalls to the first corner of the patch.

[0010] An advantage of locating the feed points of the antenna element at the corners of the inverted-cup patch are ease of construction and improving radiation efficiency of the antenna; with this location of the feed point, the radiating element radiates waves polarized along the diagonals of the inverted-cup patch.

[0011] A further advantage is that ultra-wideband co-polarized radiation pattern and polarization purity, i.e., low level of cross-polarization, may be achieved with a single feed for each of the two polarizations. This is a clear advantage over, for example, patch antenna designs that require an additional feed (of equal amplitude and a 180° phase shift) per polarization in order to counteract the effects brought about by the excitation of higher-order modes contributing to polarization impurity of the antenna.

[0012] The first feed probe and/or the second feed probe may be disposed within a respective cut-out. An advantage of the cut-outs at all four corners of the inverted-cup patch is to extend the input-impedance bandwidth of the antenna element; this also happens to further ease construction of the antenna element.

[0013] The first feed probe and/or the second feed probe may be coupled to the planar member at a position at or adjacent a respective corner thereof.

[0014] The antenna element may further comprise a metallic pedestal, the inverted cup patch being mounted so as to define a spacing between the patch and the pedestal. An advantage of the pedestal is to extend the port-to-port isolation bandwidth to higher frequencies and also deepen the already wide input-impedance match of the patch. In embodiments, the pedestal may comprise an intermediate step between the external walls and an upper surface thereof.

[0015] The spacing may comprise an air gap. Alternatively, a dielectric spacer is disposed in said spacing. Alternatively, the spacing is provided by a combination of an air gap and a dielectric spacer.

[0016] In one embodiment, the antenna element further comprises, at a third corner of the patch, diagonally opposite the first corner, a first support element for providing mechanical support to the patch and/or, at a fourth corner of the patch, diagonally opposite the second corner, a second support element for providing mechanical support to the patch. The first support element may comprise a post of substantially the same form as the first feed probe and/or the second support element may comprise a post of substantially the same form as the second feed probe. The first support element and/or the second support element may be made of dielectric. The support elements provide additional support to the patch and maintain the patch in a stable position.

[0017] In another embodiment, the antenna element further comprises, at a third corner of the patch, diagonally opposite the first corner, a metallic third feed probe and at a fourth corner of the patch, diagonally opposite the second corner, a metallic fourth feed probe.

[0018] The first feed probe, the second feed probe, the third feed probe and/or the fourth feed probe may be shaped and dimensioned so as to provide, in use, mechanical support to the patch.

[0019] The patch may be dimensioned such that the total distance (i) between the first feed probe and a corner of the planar member at a third corner of the patch, opposite the first corner, and/or (ii) between the second feed probe and a corner of the planar member at a fourth corner of the patch, opposite the second corner, defined along the free edges of the sidewalls via the portions of the edges of the planar member from which respective sidewalls extend, is substantially equal to ½ wavelength at the lowest operating frequency of the antenna element.

[0020] The first feed probe, the second feed probe, the third feed probe and/or the fourth feed probe may be coupled to the patch by (a) direct connection or (b) proximity coupling.

[0021] The antenna element may be adapted to be mounted, in use, on a metallic ground plane, and the antenna element may further comprise: a full or partial metallo-dielectric enclosure, adapted to be mounted, in use, on the ground plane so as to enclose the patch, partially contain the electromagnetic fields radiated by the patch and prevent ingress of fluid and/or debris. The enclosure may be substantially box shaped.

[0022] An advantage of the enclosure is to assist in controlling unwanted field modes. A further advantage is that the enclosure reduces mutual coupling of electromagnetic energy to any adjacent antenna, such as when the radiating element is used to form an array. As yet another advantage, the enclosure may contribute to widening the port-to-port isolation bandwidth to higher frequencies. In embodiments, the internal dimensions of the enclosure exceed the dimensions (footprint) of the pedestal.

[0023] The enclosure may include, on an internal or external surface thereof a metallic parasitic element; wherein the parasitic element is disposed, in use, adjacent the side of the planar member opposite said sidewalls such that the planes of the planar member and the parasitic patch are substantially parallel. An advantage may be that all internal metallic surfaces of the antenna, including the floating parasitic patch, are protected from corrosion. A further advantage of parasitic element may be to, firstly, deepen (as opposed to widen) the input-impedance match at higher frequencies and, secondly, widen the port-to-port isolation bandwidth at higher frequencies.

[0024] According to a second aspect of the invention, there is provided a cup-shaped patch for use in the antenna element of any preceding claims.

[0025] Preliminary results indicate that, with embodiments of the invention, a port-to-port isolation of about 18-20 dB may be achievable over a relative bandwidth of 39%. An input-impedance match of 8-10 dB may be feasible over the same relative bandwidth. Further improvement of input-impedance match can be achieved in combination with lumped elements.

[0026] Further particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Some embodiments of the apparatus and/or methods in accordance with embodiment of the present invention are now described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows an exploded view of antenna element 100 according to an embodiment of the invention;

Figure 2 shows a patch 1 used in the antenna element in Fig. 1 and the substantially lowest-operating frequency resonant path of the surface current on the patch - current on front surface (solid-line arrows); current on back surface (dotted-line arrows);

Figure 3 shows a partially-exploded view of the antenna element of Fig. 1, with patch 1 mounted;

Figure 4 shows a further partially-exploded view of antenna element of Fig. 1, with enclosure partially mounted;

Figure 5 shows an exploded view of antenna element 100 of Fig. 1, viewed from below;

Figure 6 shows the antenna element of Fig. 1, fully assembled;

Figure 7 shows a plot against frequency of scattering parameters $|S_{11}|$ (solid line) and $|S_{21}|$ (dashed line) for the antenna element of Fig. 1;

Figure 8 shows a plot against frequency of co-polarized far-field gain radiation pattern-E-plane cut (solid line), mid-plane cut (dashed line) and H-plane cut (dash-dotted line) - for the antenna element of Fig. 1 ;

Figure 9 shows a plot against frequency of cross-polarized far-field gain radiation pattern - E-plane cut (solid line), mid-plane cut (dashed line) and H-plane cut (dash-dotted line) - for the antenna element of Fig. 1; and

Figure 10 shows a plot against frequency of peak far-field gain -peak co-polarized gain (solid line) and peak cross-polarized gain (dashed line) - for the antenna element of Fig. 1.

DESCRIPTION OF EMBODIMENTS

[0028] As used herein, "ultra-wideband" is defined by the International Telecommunication Union Radiocommunication Sector (ITU-R) and the U.S. Federal Communications Commission (FCC) as applicable to an antenna whose emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the centre frequency.

[0029] An object of the_present invention is to extend the overall bandwidth of the antenna beyond the known limits of patch antennas. The present invention further seeks to provide a radiating antenna element with a low profile.

[0030] The present invention further seeks to provide, according to embodiments, a radiating antenna element capable of dual-slant linear polarization operation and/or which is suitable for ultra-wideband operation, where the wideband operation applies to the antenna input-impedance match, isolation between the two ports of the antenna corresponding to the two operating polarizations, the co-polarized far-field radiation pattern of the antenna and/or the polarization purity of the antenna.

[0031] Figure 1 shows an exploded view of antenna element 100 according to an embodiment of the invention. The antenna element 100 includes a rectangular metallic patch 1 and one or more metallic feed probes 4a, 4b. (In the illustrated embodiment, a configuration for dual-slant linear polarization operation is shown, employing one metallic feed probes 4a, 4b for each polarisation. However, it will be appreciated by persons skilled in the art that, for certain applications, one feed probe only may be deployed - when operation with a single linear polarization is desired.) In the embodiment of Fig. 1, the patch 1, a pedestal 3 and feed probes 4 are mounted, in use, with respect to a metallic ground plane 2, and metallic pedestal 3 may be mounted on and electrically connected to the ground plane 2. The patch 1 and pedestal 3 may be made from, for example, copper.

[0032] Patch 1 comprises an upper member 102. In this embodiment, upper member 102 is rectangular; however, the upper member 102 may be substantially rectangular, in that it has a polygonal or other form, and may, in embodiments, comprise a polygon whose number of sides is a multiple of 4, and "substantially rectangular" shall be construed accordingly.

[0033] In this embodiment, upper member 102 is planar; however, the upper member 102 may be substantially planar, in that it has a generally flat or similar form that approximates to planar, and may be such that its depth is a small percentage (e.g. 0-10% or 0-5%) of its width, or such that a set of points on its lowermost extremities or on its uppermost extremities lie in the same plane; and "substantially planar" shall be construed accordingly.

[0034] The patch 1 has four downward-bent sidewalls 5a, 5b, 5c, 5d only two of which (5a, 5b) are shown in Fig. 1, thereby forming an inverted cup with a rectangular cross-section. Substantial cut-outs 6a, 6b, 6c, 6d (6c is not shown in Fig. 1) are cut along the corners formed by the vertical sidewalls 5a, 5b, 5c, 5d of the patch 1. The cut-outs 6a, 6b, 6c, 6d may be substantial and may be far larger than mere slits, as discussed below in relation to Fig. 2. The resulting geometry of the inverted-cup patch 1 together with the feeding arrangement may provide for a variety of resonant paths of the surface current on the inverted-cup patch 1, and may thereby create an enabling mechanism for an ultra-wideband input-impedance bandwidth of the antenna.

[0035] In certain embodiments, the antenna element 100 is surrounded by a metallo-dielectric enclosure 104, as discussed in further detail below.

[0036] In addition, passages 103 (only one of which is visible) may be provided in ground plane 1 so as to allow feed probes 4a, 4b to pass through ground plane 1 while being spaced apart from and electrically isolated from it.

[0037] Figure 2 shows a patch 1 used in the antenna element in Fig. 1, in which sidewalls 5a, 5b, 5c, 5d extend from edges 106a, 106b, 106c, 106d of the upper member 102, so as to define cut-outs 6a, 6b, 6c, 6d. The size of the cut-outs 6a, 6b, 6c, 6d may be substantial. For example, the size of the cut-outs may be such that the distance d_c between an edge 109c of a sidewall 5c and the corner 108c of the planar member 102 is approx. 1.0-2.0x, or approx. 1.0-1.5x, the cross-sectional diameter of the feed probes 4a, 4b. In any event, d_c, and consequently the distance ("inter-edge distance") between edges 109c and 109d on sidewalls 5c and 5d, respectively, is such that the radiating antenna element is capable of ultra-wideband operation. With regard to the latter, in embodiments, the inter-edge distance may be such that (a) the antenna element is capable of emitting a signal bandwidth greater than or equal to (i) 25%, (ii) 30%, (iii) 35% or (iv) 39% of the centre frequency of the antenna element.

[0038] The patch 1 is fed by one or more feeding probes. In this embodiment (Fig. 1) two feed probes 4a, 4b are employed, however 1, 2 or more feed probes per polarisation orientation may be employed. The probes 4 can be either directly connected or proximity-coupled to the patch 1. In Fig. 2, probe 4a is shown connected to (upper member 102 of) patch 1; however in other embodiments, feed probes 4a, 4b may be coupled to other parts of the patch 1. In this embodiment (with two feed probes 4a, 4b), feed probe 4b (not shown) is to be connected at location 110b adjacent corner 108b of upper member 102. The upper member 102 includes further corners 108a, 108c and 108d.

[0039] There are shown in Fig. 2 the substantially lowest-operating frequency resonant paths of the surface current on the inverted-cup patch 1 - current on front, i.e., visible, surface (solid-line arrows) and current on back, i.e., invisible, surface (dotted-line arrows); the surface currents flow on the inner surface (generally labelled 112) of the inverted-cup patch 1. In certain embodiments, the patch 1 is sized such that each of the paths (solid line/dotted line) is substantially equal to ½ wavelength at the lowest operating frequency of the antenna element. For example, for the first feed probe 4a connected to the patch 1 (i.e. at location 110a in Fig. 2) the surface-current path extends from location 110a at corner 108a to (diagonally opposed) corner 108c of the upper member 102. It will be appreciated that similar paths are generated for a second feed probe 4b (Fig. 1) connected to the patch 1 (i.e. at location 110b in Fig. 2), but with the paths extending from location 110b at corner 108b to (diagonally opposed) corner 108d of the upper member 102.

[0040] Figure 3 shows a partially-exploded view of the antenna element of Fig. 1, with patch 1 mounted. In this embodiment, for operation with dual-slant (orthogonal) linear polarization, a second feed point (110b; Fig. 2) is located in an adjacent corner 108b of the inverted-cup patch 1. While the input-impedance bandwidth of such an inverted-cup patch 1 fed in either of its corners is fundamentally very wideband, the port-to-port isolation in dual-polarization operation is narrowband, centred about the patch's lowest resonant frequency. Therefore the radiating element according to embodiments of the present invention may further include the metallic pedestal 3, which may extend the port-to-port isolation bandwidth to higher frequencies and also deepen the already wide input-impedance match of the patch. For ease of construction, the pedestal may have large cut-outs at its corners to fully accommodate the feeding probes 4a, 4b.

[0041] In this embodiment, there is a gap 7a between the patch 1 and the pedestal 3, i.e. between distal edge of sidewall 5a and surface 116 on the pedestal 3 (the situation being the same for the other sidewalls 5b, 5c, 5d). In this embodiment, in order to optimise the design in relation to emitted bandwidth, the pedestal 3 is provided with an intermediate step 118 between the external walls 120 and the surface 116 of the pedestal 3.

[0042] The gap 7a can be an air gap or, alternatively, formed by a combination of one or more dielectric spacers (not shown) positioned between the patch 1 and the pedestal 3, or a combination of both air gap and such spacers. This configuration of the inverted-cup patch 1 and the pedestal 3 principally radiates to free space through the air gap 7a and the cut-outs 6a, 6b, 6c, 6d in the inverted-cup patch 1.

[0043] It will be appreciated that the use of two feed probes 4a, 4b assists in providing mechanical support to the patch 1, to support it spaced from pedestal 3. Thus, the inverted-cup patch 1 is held elevated above the pedestal 3, thereby forming the air gap 7a, by the two metallic probes 4a, 4b that also feed the inverted-cup patch 1, the feeding probes 4a, 4b thereby advantageously performing a dual purpose.

[0044] Figure 4 shows a further partially-exploded view of antenna element 100 of Fig. 1, with enclosure 104 partially mounted. In certain embodiments, the antenna element 100 may be surrounded by a metallic body section 9 of enclosure 104. In addition, a dielectric or metallo-dielectric cover 11 may be used to seal the enclosure 102. In the illustrated embodiment, the internal dimensions of the enclosure 104 exceed the dimensions (footprint) of the pedestal 3.

[0045] As the electrical thickness of the stackup consisting of the pedestal 3, the air gap 7a and the inverted-cup patch 1 may not be electrically negligible (e.g. 0.17 and 0. 25 wavelengths at the respective lowest and highest design frequencies), at higher frequencies the structure may necessarily also excite unwanted field modes which may degrade the integrity of the co-polarized beam radiated by the antenna as well as substantially increase the amount of cross-polarized power radiated by the antenna. In other words, the unwanted field modes would be limiting the co-polarized far-field pattern bandwidth as well as the polarization-purity bandwidth. Therefore, the radiating element is surrounded by a metallo-dielectric enclosure 104.

[0046] Figure 5 shows an exploded view of antenna element 100 of Fig. 1, viewed from below. As best seen here, a metallic parasitic patch 10 may be positioned above the top surface of the patch 1. The cover 11 may comprise a dielectric substrate/superstrate, with the parasitic patch 10 being etched onto it. The cover 11 may be mounted on body section 9 so that parasitic patch 10 is suspended over the aperture of the enclosure 9, and thus above and spaced apart from upper member 102 of patch 1.

[0047] Thus, the antenna element 100 according to the embodiments of the present invention may further includes a floating (i.e., ungrounded) parasitic patch 10 proximity-coupled to the inverted-cup patch 1. The parasitic patch 10 may be located at a small elevation above the inverted-cup patch 1. In certain embodiments, the floating parasitic patch can be supported over the inverted-cup patch 1 by a dielectric spacer (not shown) positioned on top of the inverted-cup patch 1; however, in the illustrated embodiment, the parasitic patch 10 is provided on a printed-circuit board substrate suspended over the inverted-cup patch 1.

[0048] As also seen in Fig. 5 (as well as Fig. 1), in certain embodiments, for additional mechanical support of the patch 1 over the pedestal 3, one or more dielectric support posts 8c, 8d can be employed in the remaining two free corners (cut-outs 6c, 6d) of the patch 1 or near the patch's centre region. One or both of support posts 8c, 8d may be made of dielectric. One or both of support posts 8c, 8d may have substantially the same shape (or at least height, and/or a flat upper surface) of that of feed probes 4a, 4b.

[0049] In certain embodiments, each of the two feeding probes 4a, 4b, which in Figures 1-5 together provide for operation with dual-slant linear polarization, can be transitioned to the conventional metallic microstrip line 12 on the bottom surface of a standard radiofrequency/microwave substrate sheet material 13 whose top surface forms the ground plane 2. As used herein, the term "metallic" refers to parts with electrically conducting surfaces; as such, the parts can be manufactured in several ways, e.g., as solid or sheet metals, electrically conducting plastics or metalized plastics.

[0050] Figure 6 shows the antenna element 100 of Fig. 1, fully assembled, including body 9 and cover 11 mounted on the ground plane 2, thus preventing ingress of liquid or debris.

[0051] Figure 7 shows a plot against frequency of scattering parameters $|S_{11}|$ (solid line) and $|S_{21}|$ (dashed line) for the antenna element 100 of Fig. 1. A full-wave analysis has been performed to calculate the scattering parameters and far-field gain radiation patterns of the antenna element 100 depicted in Figures 1-5. Ohmic losses are included in the calculations; and in this embodiment copper (Cu) has used for all metallic parts. In Figure 7, vertical dotted lines delimit the operating frequency band. Figure 7 includes the frequency-dependence plot 21 of the magnitudes of the input reflection coefficient 22 ($|S_{11}|$) and the forward transmission coefficient 23 ($|S_{21}|$). The antenna element 100 may have an operating frequency band of 1.55-2.30 GHz (i.e., a relative bandwidth of 39.0%), which is delimited by the markers f_1 and f_2 in the plot 21. The local minimum in $|S_{11}|$ around 1.65 GHz is due to the lowest-frequency resonance of the inverted-cup patch 1; as discussed above, the corresponding resonant path of the surface current on the patch 1 is shown in Figure 2.

[0052] Figure 8 shows a plot against frequency of co-polarized far-field gain radiation pattern-E-plane cut (solid line), mid-plane cut (dashed line) and H-plane cut (dash-dotted line) - for the antenna element of Fig. 1; and Figure 9 shows a plot against frequency of cross-polarized far-field gain radiation pattern - E-plane cut (solid line), mid-plane cut (dashed line) and H-plane cut (dash-dotted line).

[0053] Figures 8 and 9 show the typical plots 31 and 41 of the respective co- and cross-polarized far-field gain radiation patterns at 2 GHz. Co-polarized beam integrity and good polarization purity are observed throughout the design operating frequency band.

[0054] Figure 10 shows a plot against frequency of peak far-feld gain - peak co-polarized gain (solid line) and peak cross-polarized gain (dashed line) - for the antenna element of Fig. 1. Vertical dotted lines delimit the operating frequency band. In Fig. 10, plot 51 is of the peak co-polarized far-field gain 52 and plot 53 is of the peak cross-polarized far-field gain. Over the operating frequency band of 1.55-2.30 GHz, the peak co-polarized gain varies between 5.29 and 8.16 dBi, while the peak cross-polarized gain does not exceed -0.91 dBi. The results demonstrate the radiating element is suitable for utilization in antenna arrays as well as a standalone antenna.

[0055] The present inventions may be embodied in other specific apparatus and/or methods. The described embodiments are to be considered in all respects as only illustrative and not restrictive. In particular, the scope of the invention is indicated by the appended claims rather than by the description and figures herein. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. A radiating antenna element (100), comprising:

a metallic patch (1), the patch (1) having a cup-shaped form and comprising a substantially rectangular substantially planar member (102) and a sidewall (5a, 5b, 5c, 5d) extending transverse to the plane of the planar member (102) from each edge (106a, 106,b, 106c, 106d) of the planar member (102);

a cut-out (6a, 6b, 6c, 6d) defined at each corner of the patch (1), whereby at each corner edges of respective pairs of sidewalls (5a, 5b, 5c, 5d) are spaced apart by a distance such that the radiating antenna element is capable of ultra-wideband operation; and

at least a metallic first feed probe (4a), the first feed probe (4a) being coupled to the patch (1) at a position at or adjacent a first corner thereof.

2. The antenna element as claimed in claim 1, wherein said distance between respective pairs of sidewalls (5a, 5b, 5c, 5d) is such that (a) the antenna element is capable of emitting a signal bandwidth greater than or equal to (i) 25%, (ii) 30%, (iii) 35% or (iv) 39% of the centre frequency of the antenna element, and/or (b) the first feed probe (4a) may be mounted within the cut-out (6a, 6b, 6c, 6d).

3. The antenna element as claimed in claim 1 or 2, further comprising a second feed probe (4b);
wherein the second feed probe (4b) is coupled to the patch (1) at a position at or adjacent a second corner of the patch (1), the second corner being at an opposite end of one of the sidewalls (5a, 5b, 5c, 5d) to the first corner of the patch (1).

4. The antenna element as claimed in claim 1, 2 or 3, wherein the first feed probe (4a) and/or the second feed probe (4b) is disposed within a respective cutout (6a, 6b, 6c, 6d).

5. The antenna element as claimed in any preceding claim, wherein the first feed probe (4a) and/or the second feed probe (4b) is coupled to the planar member (102) at a position (110a,110b) at or adjacent a respective corner (108a,108b) thereof.

6. The antenna element as claimed in any preceding claim, further comprising a metallic pedestal (3), the patch (1) being mounted so as to define a spacing (7a) between the patch (1) and the pedestal (3).

7. The antenna element as claimed in claim 6, wherein (i) the spacing (7a) comprises an air gap, (ii) a dielectric spacer is disposed in said spacing (7a), or (iii) the spacing (7a) is provided by a combination of an air gap and a dielectric spacer.

8. The antenna element as claimed in any preceding claim, further comprising, at a third corner of the patch, diagonally opposite the first corner, a first support element (8c) for providing mechanical support to the patch (1) and/or at a fourth corner of the patch, diagonally opposite the second corner, a second support element (8d) for providing mechanical support to the patch (1).

9. The antenna element as claimed in claim 8, wherein the first support element (8c) comprises a post of substantially the same form as the first feed probe (4a) and/or the second support element (8d) comprises a post of substantially the same form as the second feed probe (4b).

10. The antenna element as claimed in any claim 8 or 9, wherein the first support element (8c) and/or the second support element (8d) is made of dielectric.

11. The antenna element as claimed in any of claims 1 to 7, further comprising, at a third corner of the patch, diagonally opposite the first corner, a metallic third feed probe and at a fourth corner of the patch, diagonally opposite the second corner, a metallic fourth feed probe, and/or wherein the first feed probe (4a), the second feed probe (4b), the third feed probe and/or the fourth feed probe are shaped and dimensioned so as to provide, in use, mechanical support to the patch (1), and/or wherein the first feed probe (4a), the second feed probe (4b), the third feed probe and/or the fourth feed probe is coupled to the patch by (a) direct connection or (b) proximity coupling.

12. The antenna element as claimed in any preceding claim, wherein the patch (1) is dimensioned such that the total distance

(i) between the first feed probe (4a) and a corner (108c) of the planar member (102) at a third corner of the patch, opposite the first corner, and/or (ii) between the second feed probe (4b) and a corner (1 08d) of the planar member (102) at a fourth corner of the patch, opposite the second corner, defined along the free edges of the sidewalls (5a, 5b, 5c, 5d) via the portions of the edges of the planar member (102) from which respective sidewalls (5a, 5b, 5c, 5d) extend, is substantially equal to ½ wavelength at the lowest operating frequency of the antenna element (100).

13. The antenna element as claimed in any preceding claim, adapted to be mounted, in use, on a metallic ground plane (2), the antenna element further comprising:

a full or partial metallo-dielectric enclosure (104), adapted to be mounted, in use, on the ground plane (2) so as to enclose the patch (1), partially contain the electromagnetic fields radiated by the patch (1) and prevent ingress of fluid and/or debris.

14. The antenna element as claimed in claim 13, wherein the enclosure (104) is substantially box shaped and includes, on an internal or external surface thereof a metallic parasitic element (10); wherein the parasitic element (10) is disposed, in use, adjacent the side of the planar member (102) opposite said sidewalls (5a, 5b, 5c, 5d) such that the planes of the planar member (102) and the parasitic patch (10) are substantially parallel.

15. A cup-shaped patch for use in the antenna element of any preceding claim.

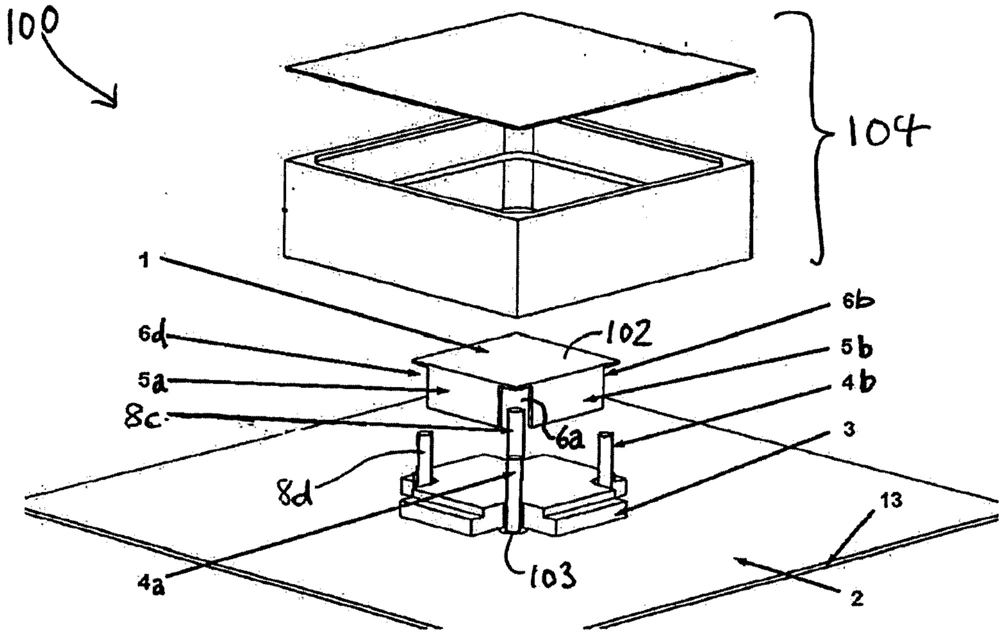

FIGURE 1

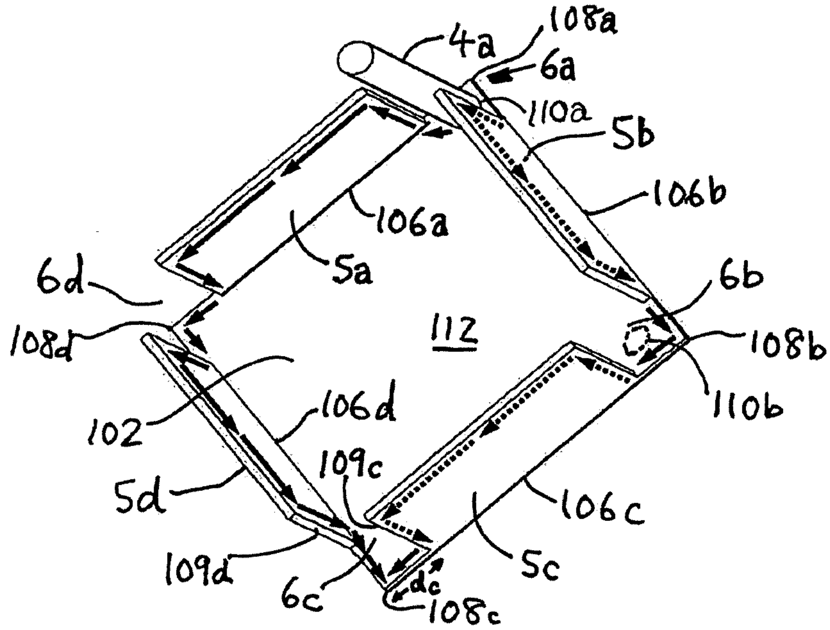

FIGURE 2

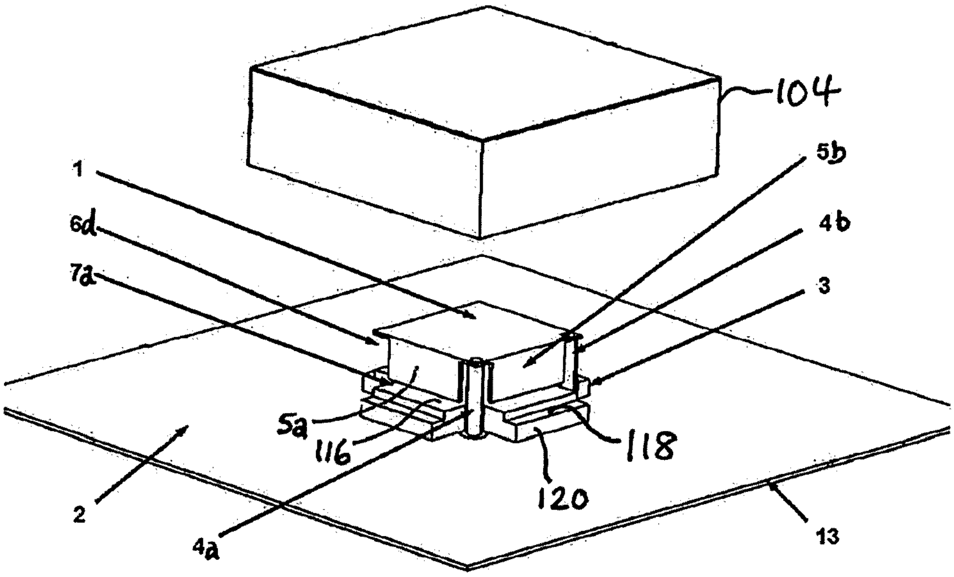

FIGURE 3

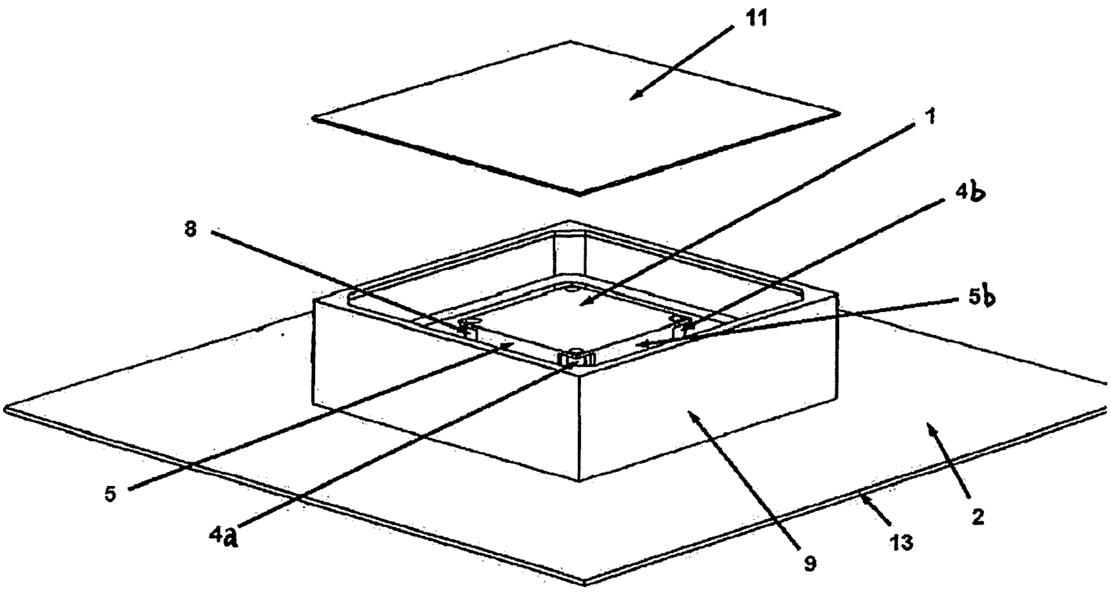

FIGURE 4

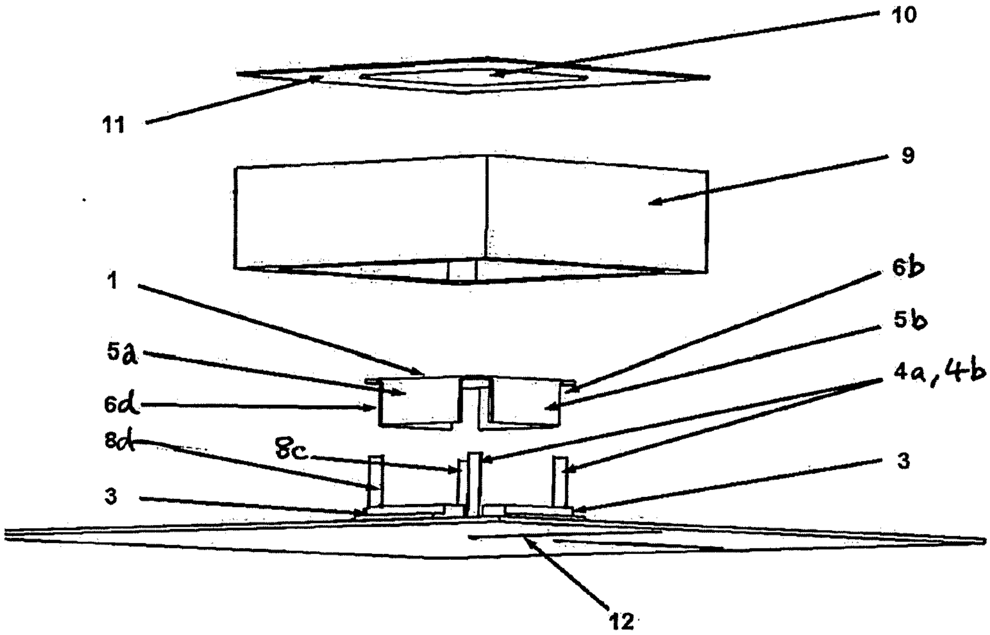

FIGURE 5

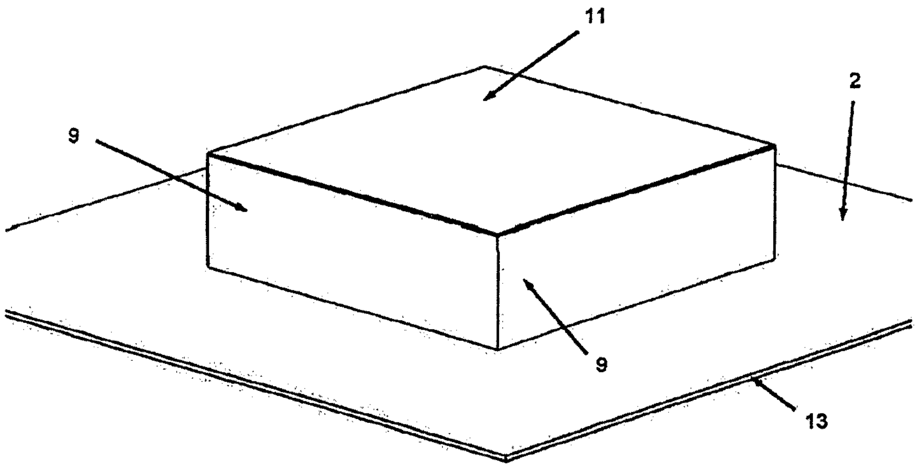

FIGURE 6

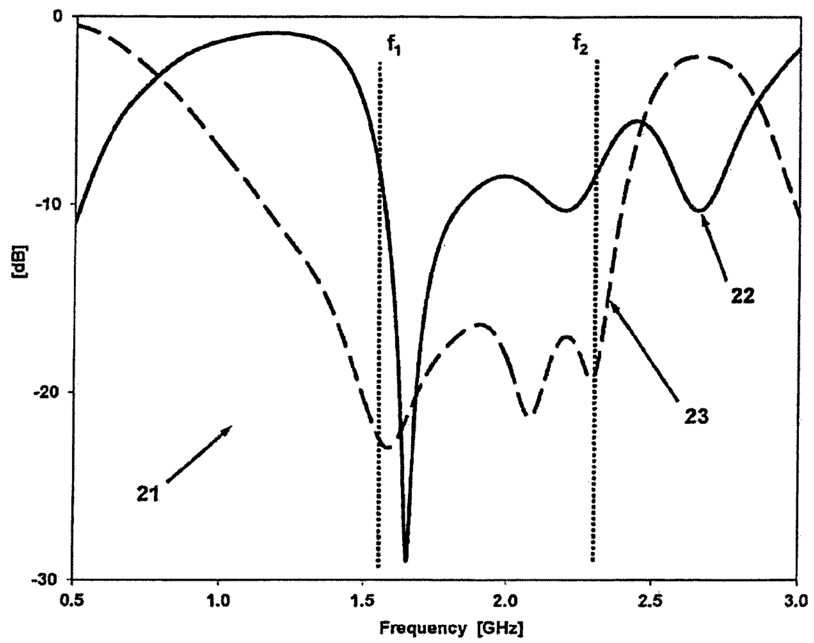

FIGURE 7

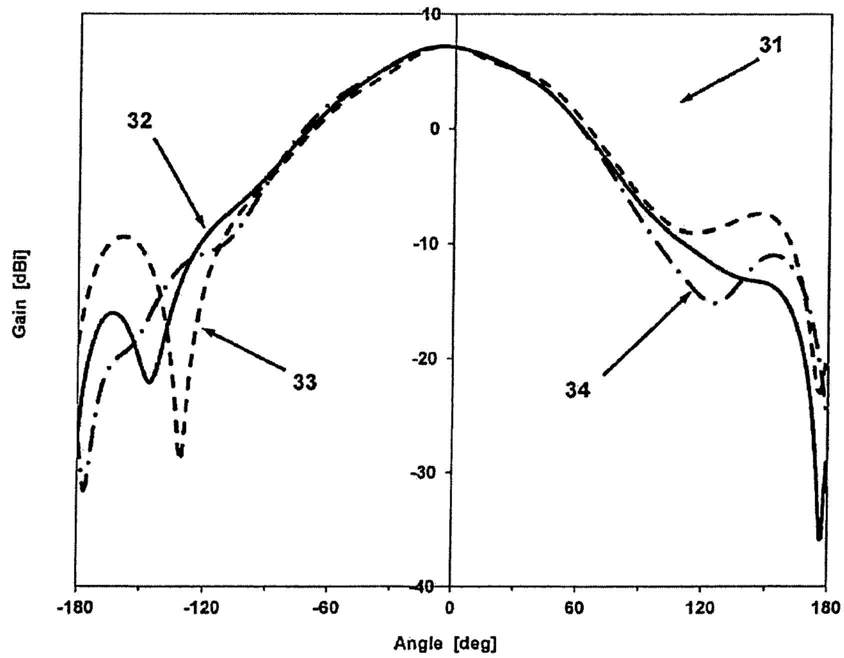

FIGURE 8

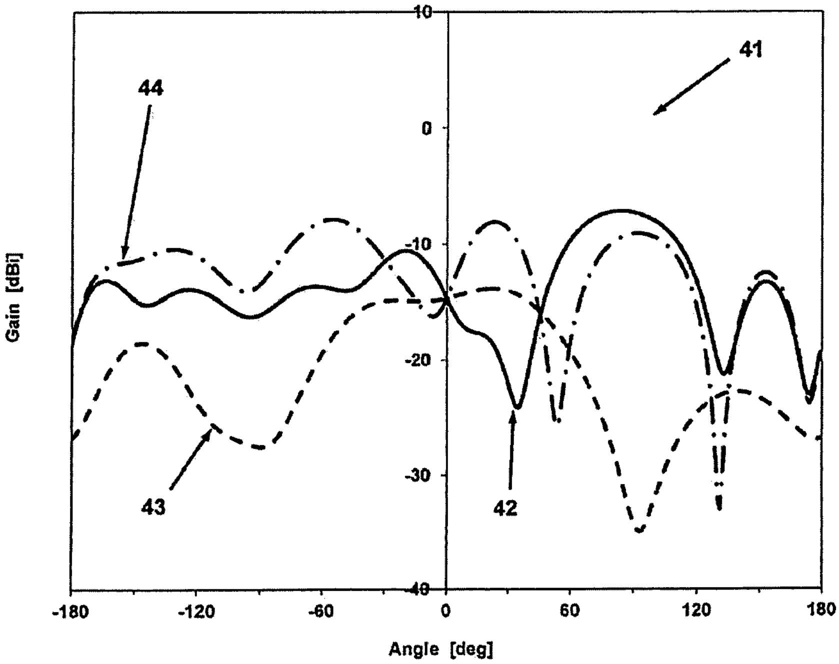

FIGURE 9

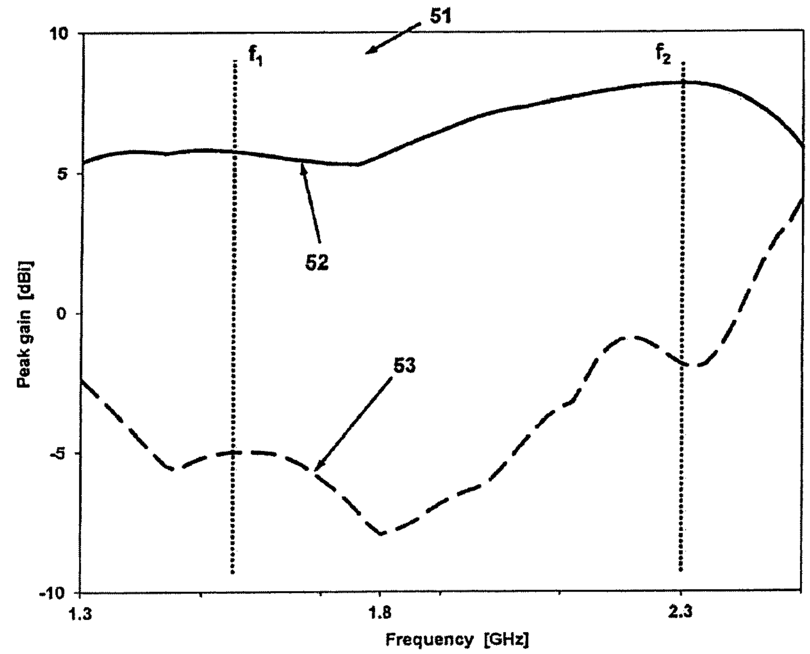

FIGURE 10

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EUROPEAN SEARCH REPORT

Application Number
EP 14 36 0005

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 633 646 A (STRICKLAND PETER C [CA]) 27 May 1997 (1997-05-27) * column 1, line 64 - column 4, line 5; figures 1-4 * -----	1-3,5, 8-15	INV. H01Q21/06 H01Q9/04 H01Q9/42
X	US 6 765 537 B1 (APOSTOLOS JOHN T [US]) 20 July 2004 (2004-07-20) * abstract * * column 1, line 52 - column 3, line 49; figures 1-4 * -----	1-3,5, 8-15	
X	US 2004/145521 A1 (HEBRON THEODORE SAMUEL [US] ET AL) 29 July 2004 (2004-07-29) * paragraphs [0044] - [0080]; figures 1-2 * -----	1-3,5, 8-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 July 2014	van Norel, Jan

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EPO FORM 1503 03.82 (P04C01)

CATEGORY OF CITED DOCUMENTS

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21-07-2014

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82